ELSEVIER
Available online at www.sciencedirect.com
SciVerse ScienceDirect
Energy Procedia 16 (2012) 1964 – 1971
Energy Procedia

2012 International Conference on Future Energy, Environment, and Materials

Effects of Pre-fermentation and Influent Temperature on the Removal Efficiency of COD, NH_4^+-N and PO_4^{3-}-P in Slaughterhouse Wastewater by Using SBR

Yanping Jia[1,2,3], Chao Gao[1], Lanhe Zhang[1*], Guiquan Jiang[4]

[1] *College of Chemical Engineering, Northeast Dianli University, Jilin 132012, China.;*
[2] *National Engineering Research Center of Urban Water Resources, Harbin 150090, China.*
[3]*Food Science College,Shenyang Agricultural University,Shenyang, Liaoning,110161, China*
[4] *Forestry college of Beihua University, Jilin 132013, China*
** Corresponding author.*

Abstract

A sequencing batch reactor (SBR) was used to remove COD, NH_4^+-N and PO_4^{3-}-P in slaughterhouse wastewater at different temperatures. A complete operation cycle was 7h, which consisted of fill, aeration(5h), settling(1h), stationary(1h) and drawing. Conventional treatment technologies were unsuccessful in treating slaughterhouse wastewater because it contained substantial amounts of fat, oil and grease (FOG). The SBR process showed great nutrient removal performances after 7 days prefermentation. The removals of COD, NH_4^+-N and PO_4^{3-}-P were 99%, 85% and 99%, respectively. The increase in effluent volatile fatty acid (VFA) and phosphate concentrations after prefermentation may explain the high levels of biological carbon, nitrogen and phosphorus removal observed. The results also showed that 30℃ was found to be the most suitable temperature as the removal efficiency of COD, NH_4^+-N and PO_4^{3-}-P was 96%, 92% and 91%, respectively.

Keywords： *slaughterhouse wastewater; SBR; pre-fermentation; temperature*

1. Introduction

The slaughterhouse industry is a very old human activity and, although it is still a relatively small scale industrial sector, its environmental impact has grown considerably due to the increase in plant production. The wastewater generated in meat processing plants contains high amounts of biodegradable organic matters, usually varying from 1100 to 2400 mg /L in terms of BOD_5, with the soluble fraction varying between 40% and 60%. The insoluble fraction is formed by colloidal and suspended matters, in the form

 doi:10.1016/j.egypro.2012.01.300

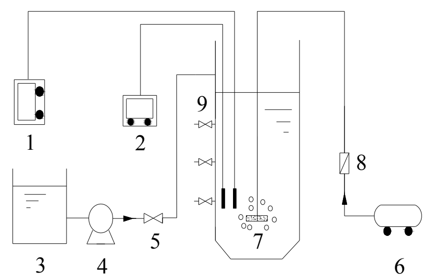
of fats, proteins and cellulose, which can be degraded slowly in anaerobic reactors[1~3]. Depending on whether preliminary treatment is carried out and its efficiency, the concentrations of contaminants in a slaughterhouse wastewater can be variable[4~6]. For large-scale slaughterhouses, on-site biological treatment removes organic carbon and nutrients before the wastewater is discharged to surface waters or local wastewater treatment plants[7~9]. Most slaughterhouse wastewater treatment systems utilize activated sludge, stabilization ponds and anaerobic reactors as main biological treatment technologies. The high energy demand for aeration and massive sludge generated increase the operating costs of the treatment system, which limit the application of the aerobic technology as a main biological treatment of slaughterhouse wastewater[10,11]. A sequencing batch reactor (SBR) is preferred for its small space requirement, low engineering investment and operational cost, effective treatment and convenient operation and management[12,13]. Previous researchers suggested that the application of pretreatment to hydrolyse partial fat particles could accelerate the anaerobic treatment of slaughterhouse wastewater. This study aimed to (1) investigate the effects of prefermentation on slaughterhouse wastewater by using SBR;(2)determine the effect of temperature(10℃,20℃,30℃) on removal efficiency of COD,NH_4^+-N,PO_4^{3-}-P in slaughterhouse wastewater.

2. Materials and Methods

2.1 Experimental setup

A schematic diagram of the experimental set up is depicted in Fig.1. Working volume of the SBR was 3.5 L. Aeration was provided by using an air pump and a sparger. Agitation speed was varied between 150 and 200 rpm. pH, dissolved oxygen (DO) and oxidation-reduction potential (ORP) of the wastewater were measured and adjusted to desired levels for each phase of the operation. An operation cycle consisted of five steps, namely, feeding→aeration (5h) → settling (1h)→stationary (1h)→drawing. Sludge age was kept constant at 14 days.

The seed sludge from an upflow anaerobic sludge blanket reactor was inoculated into the SBR at the beginning of the cultivation. During the start-up period, the reactor was operated for 90 days until the removal rate of COD and NH_4^+-N were over 95% and 85%, respectively.



1 DO monitor 2 pH monitor 3 influent tank 4 influent pump 5 influent valve 6 aeration pump 7 pump noddle 8 air flowmeter 9 effluent valve

Fig.1 Schematic diagram of SBR system

2.2 Wastewater Composition

The wastewater used in this study was from a local abattoir in Jilin, China. The raw wastewater was subjected to 7 day pre-fermentation before being pumped into the SBR. No inoculum was introduced in the pre-fermentor. The microbial population in the raw abattoir wastewater was used to carry out the fermentation. The temperature inside the reactor was kept at 30℃. The aim of pre-fermentation was to decrease the concentration of fat, oil, grease and COD, and increase the level of easily biodegradable COD, especially volatile fatty acids (VFAs), which was critical for biological phosphorus removal. The characteristics of the pre-fermented raw wastewater and the slaughterhouse wastewater were compared in Table 1.

Table1 Characteristics of different types of wastewater used in this study

Parameter	Slaughterhouse wastewater	Pre-fermented raw wastewater
COD(mg/L)	1900-2480	785-940
VFA(mg COD/L)	152-265	531-717
TN(mg/L)	186-215	295-430
NH_4^+-N(mg/L)	102-126	195-237
TP(mg/L)	30-47	35-52
PO_4^{3-}-P(mg/L)	29-43	33-47

2.3 Analytical methods

COD, NH_4^+-N, NO_2^--N, NO_3^--N, TN, MLSS, Total phosphate(TP) and volatile fatty acids(VFA) were measured by using Standard Methods. COD was measured by potassium dichromate titrimetric method. Ammonium nitrogen (NH_4^+-N), nitrite-nitrogen (NO_2^--N), nitrate-nitrogen (NO_3^--N) and total nitrogen (TN) were determined by Nessler's Reagents spectrophotometer, Spectrophotometric method with N-(1-naphthyl) ethy lenediamine, ultraviolet spectrophotometric method and alkaline potassium persulfate digestion-UV spectro photometer method, respectively. DO was measured by YD-1A dissolved oxygen meter and pH was measured by PHS-3C model acidity of precision.

3. Results and discussion

3.1 Treatment of slaughterhouse wastewater after prefermentation

Evolution of the effluent composition during 10 days of anaerobic storage is presented in Table 1. After 7 days of storage, about 75% of soluble COD was in the form of VFA, mainly acetate but also propionate, butyrate, isobutyrate and isovalerate[14]. An increase of 15% in phosphate concentration was observed as a result of conversion of organic-P. NH_4^+-N was double increased, which was probably produced during the mineralization of the high soluble protein substrate in the SBR reactors. COD removal efficiencies during the prefermentation were around 65%. This abatement of COD was due to the transformation of a part of organic compounds into VFA and CO_2, and to promote bacterial growth during the acidification period. Maximal VFA concentration was obtained after 7 days of pre-fermentation. Therefore, 7 day acidification storage was determined as pre-fermentation before feeding. The process was operated for 90 days using this prefermented slaughterhouse wastewater.

Fig.2 shows variations of COD, NH_4^+-N and PO_4^{3-}-P in the SBR during 90 days. The average COD,NH_4^+-N and PO_4^{3-}-P removal efficiencies in the SBR during 50 days were 92%, 78%and 83%, respectively. By using prefermented wastewater, P release concentration increased and varied from 35 to 52mg/L, and P concentration at the end of the anoxic phase decreased and varied from 0 to 3 mg/L.

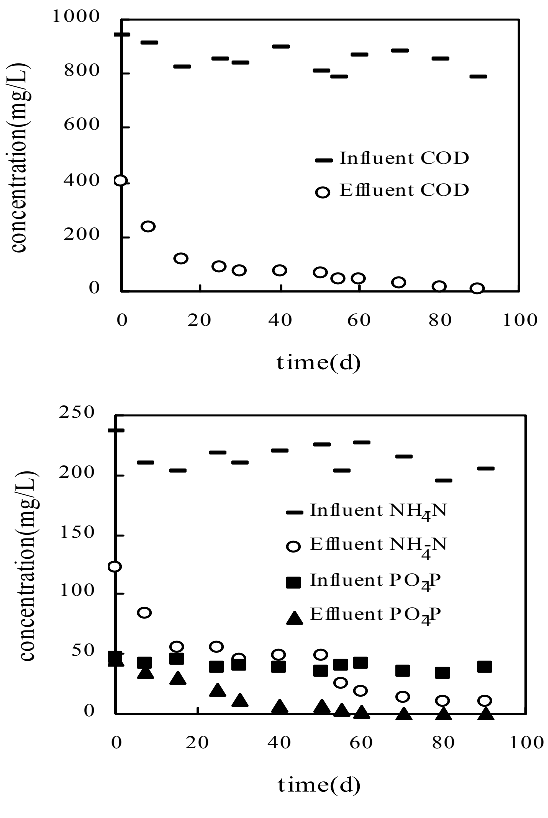


Fig 2.Characteristics of the SBR influent and effluent during 0-90 days after 7 days of pre-fermentation

This was due to the increase of VFA and P concentrations in the pre-treated effluent and to the consumption of VFA in the anaerobic phase. Prefermentation of the slaughterhouse wastewater increased the P/CODs ratio. Consequently, the P uptake increased with the increase of polyphosphate accumulating organisms (PAOs) in the activated sludge. The increase of P concentration in the wastewater allowed the increase of P uptake by the PAO in the form of poly-P granules. This intracellular stock of poly-P was used as energy for VFA consumption and P release under anaerobic conditions. Complete P removal was achieved during the last 30 days of steady state operation due to the increase of the phosphorus sludge content. However, the P release decreased between the 30th and 50th day and P was incompletely removed at the 50th day (83%). This can be explained by a particularly low P concentration in the wastewater (6mg/L). SBR fed with slaughterhouse wastewater could be successfully operated, but only for pre-fermented wastewater with high VFA concentration and P/COD ratio. On-site VFAs were produced with low operational costs and no storage or handling problems, which can make them an attractive choice as a carbon source for nutrient removal. Indeed, the conversion of fermentable COD to VFA before utilization was necessary to maintain enhanced phosphorus removal activity. After 90 days, the final COD, NH_4^+-N and PO_4^{3-}-P removal efficiencies reached 99%, 95% and 100%, respectively.

Therefore, pre-fermentation was advisable for better treatment of slaughterhouse wastewater containing substantial amounts of fat, oil and grease(FOG) .

3.2 The effect of temperature on slaughterhouse wastewater treatment

Temperature is a very important inluence factor to assess the overall efficiency of a biological treatment process. Temperatures below or above the optimum typically have a negative effect on nutrient removal. To obtain a maximum removal efficiencies for COD, NH_4^+-N and PO_4^{3-}-P, the temperature of the process must be considered. After 90 days start-up period[15], a series of experiments were carried out to investigate the removal of COD, NH_4^+-N and PO_4^{3-}-P at 10ºC, 20ºC and 30ºC, respectively, for 90 days. Fig.3 showed that removal efficiency of COD was about 78%, 92% and 96% at three different temperatures. The removal efficiency of COD was improved with the increase of temperature from 10℃ to 30℃. The SBR generally provided nearly adequate and complete COD removal of the wastewater at 30°C. In general, higher temperature is helpful for the COD removal. One explanation was the increasing removal efficiency of COD from 10℃ to 30℃ may have been the result of fat particle hydrolysis. Another explanation was that about one half of the COD in the wastewater was in undissolved form, and the increase in the degradation rate was attributed to a faster liquefaction of the colloidals and suspended solids (SS) under higher operating temperature. Such results were ascribed to the flexible SBR system which could remove oil, grease and suspended solids. More than 90% of COD removal was achieved throughout the entire influent COD range under average effluent COD concentration of lower than 10mg/l.

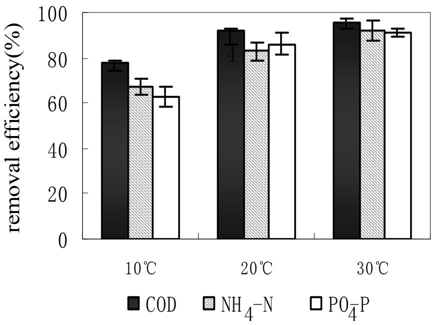


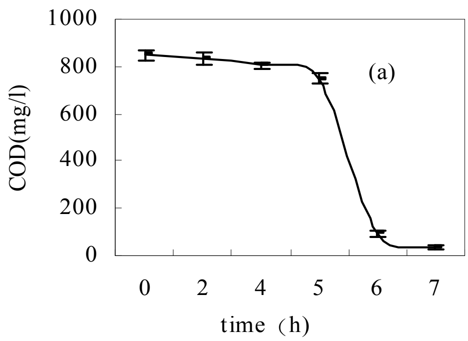
Fig 3 Removal efficiency of COD, NH_4^+-N and PO_4^{3-}-P at different temperatures

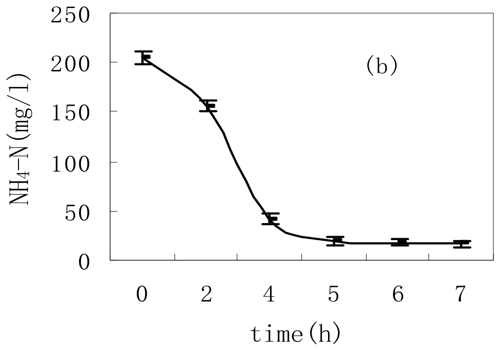
Fig.3 also showed that removal efficiency of NH_4^+-N was about 67%, 83% and 92% at three different temperatures. As shown in Fig. 3, removal efficiency of NH_4^+-N was 92% when temperature was 30℃, but its removal efficiency was only about 67% when temperature was 10℃. In the present experiment, effluent ammonia concentration below 10mg/L was regarded as complete oxidation of ammonia. A temperature of 10℃ was too low to achieve complete oxidation of ammonia. The removal efficiency of NH_4^+-N was positively correlated with the temperature in the range of 10℃-30℃, which was in accordance with the literature[16] that the nitrification rate doubled as temperature increased by 10℃ within the range of 5-30℃. Bacterial synthesis is the main nitrogen sink during anaerobic treatment. The low growth rate and yield of anaerobic bacteria translated into low overall nitrogen removal. NH_4^+-N was mainly consumed by assimilation but also by nitrification. It was clear from this study that NH_4^+-N removal can be negatively affected by low temperatures.

Fig.3 showed that removal efficiency of PO_4^{3-}-P was about 63%, 86% and 91% at three different temperatures. At 30℃, aerobic phosphate uptake was increasingly independent of phosphate release in the anaerobic zone. At 10℃, no correlation between anaerobic P-release and aerobic P-uptake was observed. The rate of P-release decreased as the operating temperature was lowered from 30℃ to 10℃. Some literatures also showed that P-release increased with increasing temperature between 4 and 37℃. In the studies performed by Panswad et al. (2003)[17], It was clear that P-removal could be negatively affected by low temperatures in the SBR system and the presence of nitrate in the anaerobic zone affected the removal efficiency of PO_4^{3-}-P. Residual nitrate in the anaerobic phase results in the consumption of influent organic compounds by denitrifiers, thus decreasing the availability of organic matter for PAO. This reduction in PAO activity was evident when temperature was reduced. As a result, P removal efficiency was higher than 90%, and P concentration was lower than 0.5 mg/L in the effluent when the temperature is 30℃. The results demonstrated that a favorable PO_4^{3-}-P removal could be achieved under optimum temperature (30℃). Increase of temperature resulted in an increase in the population of poly-P organisms, which is known to accumulate soluble orthophosphate as intracellular polyphosphate under aerobic conditions and under anaerobic conditions. It can store soluble organic carbon as intracellular polyhydroxyalkanoates. At lower temperature (10℃), poly-P bacteria was deficient for PO_4^{3-}-P reduction. As the temperature increase, it was possible that poly-P bacteria became the dominant species reducing the PO_4^{3-}-P in the wastewater.

3.3 Nutrient concentration profiles

After 180 days steady operation, samples at the beginning and at the end of each step (anaerobic/anoxic/oxic) were analyzed for COD, NH_4^+-N and PO_4^{3-}-P when the operating temperature was 30℃. Typical nutrient concentration profiles are depicted in Fig.4. Nearly 96% COD removal took place in the oxic step at the end of 7 hours of SBR operation. COD removal in the first two phases was as a result of utilization of carbonaceous compounds during denitrification. NH_4^+-N removal was negligible in the first two phases, since the only nitrogen removal mechanism in anaerobic/anoxic phases was denitrification of nitrate generated during the oxic phase of the previous cycle. Most of the NH_4^+-N was removed during the oxic phase by assimilation and nitrification resulting in 16.4 mg/L of NH_4^+-N at the end of the operation. PO_4^{3-}-P concentration was 38.4mg/L at the beginning of the cycle and slightly increased to 40.2mg/L during the first anaerobic/anoxic phases as a result of phosphate release. However, PO_4^{3-}-P concentration dropped down to 3.5mg/L at the end of the SBR operation because of assimilation and excess phosphate uptake during the oxic phase.





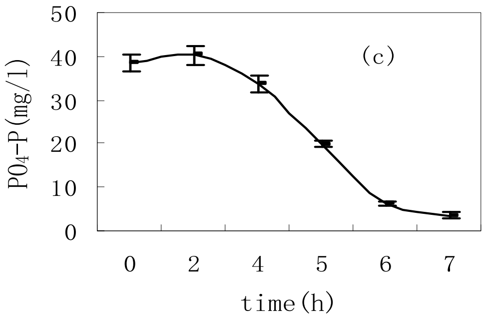


Fig.4 Changes of COD, NH_4^+-Nand PO_4^{3-}-P in the SBR at 30℃ (a)COD; (b) NH_4^+-N; (c)PO_4^{3-}-P

4. Conclusions

A SBR system was effective in removing COD, NH_4^+-N and PO_4^{3-}-P from slaughterhouse wastewater. Conclusions are listed as follows:

(1) It is necessary to pre-ferment the slaughterhouse wastewater as an integrated step for nutrient removal. This stream, which contained a high-level of VFAs, was effective in providing supplementary carbon sources for both PO_4^{3-}-P and NH_4^+-N removal. Pre-fermentation is strongly recommended in the practical treatment of slaughterhouse wastewater.

(2) Temperature is very important to assess the overall efficiency of a biological treatment process. The optimal temperature for the nutrient removal in the SBR was 30℃, and removal efficiency of COD, NH_4^+-N and PO_4^{3-}-P is 96%, 92% and 91%, respectively.

Acknowledgment

The project was supported by Foundation for Science and Technology Development Plan, Jilin Province of China (20090599) and by Foundation for Scientific Research Collaborating with Overseas Scholar, Jilin Province of China (20080705).

References

[1] M.R .Johns,Developments in wastewater treatment in the meat processing industry:a review[J].Bioresour. Technol.1995,54(3):203-216

[2] L.A.Nunez, , B..Martinez, Anaerobic treatment of slaughterhouse wastewater in an EGSB reactor[J]. Water. Sci. Technol.1999,40(8):99-106

[3] CET Caixeta,MC Cammarota,AMF Xavier.Slaughterhouse wastewater treatment:evaluation of a new three-phase separation system in a UASB reactor[J].Bioresour. Technol..2002,81(1):61-69

[4] DP Cassidy, E Belia. N and P removal from an abattoir wastewater in a SBR with aerobic granular sludge[J]. Water Res.2005, 39(19):4817-4823.

[5] R Del Pozo, V Diez. Integrated anaerobic–aerobic fixed-film reactor for slaughterhouse wastewater treatment[J]. Water Res.2005, 39(6): 1114–1122.

[6] W Fuchs,H Binder, G Mavrias, R Braun. Anaerobic treatment of wastewater with high organic content using a stirred tank reactor coupled with a membrane filtration unit[J]. Water Res. 2003,37(4):902–908.

[7] M Merzouki, N Bernet, JP Delgenes,M Benlemlih. Effect of prefermentation on denitrifying phosphorus removal in slaughterhouse wastewater[J]. Bioresour. Technol. 2005,96(12): 1317–1322.

[8] GS Mittal. Treatment of wastewater from abattoirs before land application, a review[J]. Bioresour. Technol.2006, 97(9):1119–1135.

[9] European Commission, 2005. Integrated Pollution Prevention and Control:Reference Document on Best Available Techniques in the Slaughterhouses and Animal by-Products Industries. European Commission.

[10] R Del Pozo, V Diez, S Beltran. Anaerobic pre-treatment of slaughterhouse wastewater using fixed-film reactors[J].Biores Technol.2000,71(2):143–149.

[11] W Parawira,I Kudita,MG Nyandoroh, R Zvauya.A study of industrial anaerobic treatment of opaque beer brewery wastewater in a tropical climate using a full-scaleUASB reactor seeded with activated sludge[J]. Process Biochem2005;40(2):593–599.

[12] TG Potter,B Koopman,SA Svoronos. Optimization of a periodic biological process for nitrogen removal from wastewater[J]. Water Res. 1996,30(1):142–152.

[13] XJ Bi, TY Gao. DAF-SBR treatment of meat-processing wastewater[J]. China Water Wastewater, 1998-2:;14(2):22–23.

[14] K Gungor,MB Muftugil,JA Ogejo,KF Knowlton. Prefermentation of liquid dairy manure to support biological nutrient removal[J]. Biores Technol 2009,100(7):2124-2129

[15] DI Masse, L Masse. The effect of temperature on slaughterhouse wastewater treatment in anaerobic sequencing batch reactors[J]. Biores Technol .2001,76(2):91-98

[16] JL Wang, N Yang.Partial nitrification under limited dissolved oxygen conditions[J]. Process Biochem 2004,39(10):1223–1229

[17] T Panswad,A Doungchai, J Anotai. Temperature effect on microbial community of enhanced biological phosphorus removal system[J]. Water Res.2003,37(2):409– 415.